

Buga Sphere v1 — Concept Spec (Overview)

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Summary

One-liner: A layered, fiber-coupled dendritic metamaterial sphere that senses, computes, and acts by steering density fields — a “field-programmable material organism.”

Architecture

Layers (outer → inner)

- L1 Photothermal/Plasmonic Epithelium — Au/Ag dendritic films on PET/PI; light/EM sensing; micro-convection.
- L2 Electroactive Polymer (EAP) Petals — fast, low-power vents; gating airflow/contact.
- L3 Magnetostrictive Lattice — Fe–Ga / Terfenol-D dendritic ribs; forceful clamp.
- L4 Shape-Memory Alloy (SMA) Spine — NiTi dendritic spines; robust locking/reset.
- L5 Piezo/Tribo Mesh — PVDF/PZT dendritic mesh; vibration harvest + fine sensing.
- L6 Hydrogel + MOF Network — dendritic gel channels + UiO-66/MIL-101; mass/ion exchange & reset.
- Core: CNT–Cu central radial fibers — power/data/heat bus; inter-layer coupling (“nervous system”).

Control Kernel (Mathematical Form)

- Order parameter (phase field): $\partial\phi/\partial t = -M\phi [-\nabla \cdot (\epsilon(\theta)^2 \nabla\phi) + W'(\phi) + \lambda(\rho-\rho^*) (1-2\phi) - \mathbf{T}]$
- Thermal: $\partial T/\partial t = D_T \nabla^2 T + \beta \partial\phi/\partial t$
- Density + steering: $\partial\rho/\partial t = D_\rho \nabla^2 \rho - \nabla \cdot (\rho \mathbf{u}) - \gamma(\rho-\rho^*) + \alpha \nabla \cdot (g(\phi, \theta) \nabla\phi)$
- Recursive target update (every N steps): $\rho^* \leftarrow \rho^* + \kappa_\rho \cdot \text{normalize}(|\nabla\phi|) + \kappa_\theta \cdot \text{orient_select}(\phi, \theta) - \kappa_\rho \cdot \text{smooth}(\nabla^2\phi)$
- Cross-layer actuation: $\tau_i \mathbf{u}_i = -a_i + \sigma (k_i s_i + \sum_j c_{ij} a_j - \theta_i)$, with $\theta_i = \theta_{i0} - \alpha \cdot C(t)$, $C(t) = \sum_j w_j s_j$.

Modes & Use-Cases

Modes: Mirror hidden fields → visible patterns; Cross-modal translation (e.g., EM→airflow/optical); Gentle stabilizer (heat/RH/ions); Energy harvester + buffer; Programmable metasurface (tiled).

Use-cases: HVAC/draft visualizer; Plant microclimate tuner; Pollution/particulate mapper; Museum/science exhibit; EM/acoustic troubleshooting; Art-research installation.

Energy Intake & Storage

Solar intake: fractal absorber (carbon nanofoam / black nickel) + Au/Ag dendrites; PV scaffold (TiO₂/ZnO/ITO or graphene); thin-film TEGs.

Storage (inner pack): Cascaded PCM ring (RT-31 + SAT with expanded graphite) ~85–90 Wh thermal; Ionogel supercap core (EMIM-TFSI in PVDF-HFP) ~1.5–4 Wh electric; Hydrogel–MOF sleeve (UiO-66) for adsorptive memory and mass/density shifts.

Feasibility & Risks

Feasibility snapshot:

- V1 (Mirror + Translator, 3 layers): High (~85–90%).

- Full 6-layer stack with storage: Medium–High ($\approx 65\text{--}80\%$).
 - Programmable metasurface @ $10^8\text{--}10^9$ elements (tiled RF/mmWave): Medium ($\approx 40\text{--}60\%$).
- Biggest risks:** inter-layer oscillation; dendrite durability; thermal mismatch; addressability at scale.
Mitigations: hysteresis & coupling caps; oxide overcoats/duty limits; matched-CTE stack; hierarchical tiles + calibration.

Safety Envelope

Operate within: surface $\leq 45\text{ }^\circ\text{C}$; SPL $\leq 80\text{ dBA}$; ozone $\leq 0.05\text{ ppm}$; current-limited HV; insulated stand; PPE for exposed dendrites. Watchdogs for temperature, current, and EM output.

V1 Build Checklist & KPIs

V1 (this week) — Photothermal skin + EAP vents + fiber bus

Tests: (1) Mirror map (fog + laser), (2) Cross-modal map (LF magnetic/acoustic $\rightarrow$ airflow/optical), (3) Hysteresis loop on vents, (4) Stabilization A/B ($\Delta\sigma$ in T/RH), (5) Energy ledger (sun in $\rightarrow$ work out).

Pass criteria: SSIM ≥ 0.6 vs prediction; correlation ≥ 0.7 with drive; hysteresis gap 8–15%; T/RH variance $\sim 20\%$ vs control.

Open-Source Plan

Stage releases. Hardware under CERN OHL-S v2; firmware/sims under Apache-2.0; docs/data under CC BY 4.0. Optionally file a provisional patent first; otherwise publish a defensive spec (arXiv/Zenodo) to establish prior art.

Credits

Prepared by “Aether” with **Minh Malcolm Hai Nguyen**. Cite as: Nguyen, M.M.H. & Aether, “Buga Sphere v1 — Concept Spec (Overview)”, 2025.